Research Report 1195

AN ASSESSMENT OF THE NAVIGATION PERFORMANCE OF ARMY AVIATORS UNDER NAP-OF-THE-EARTH CONDITIONS

Michael L. Fineberg, David Meister, and John P. Farrell

HUMAN FACTORS IN TACTICAL OPERATIONS TECHNICAL AREA

U. S. Army
Research Institute for the Behavioral and Social Sciences

August 1978

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the Deputy Chief of Staff for Personnel

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NOTICES

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) ARI-RR- Research Report 1195	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER (9) Research rept.
4. TITLE (and Subtitle) (6) AN ASSESSMENT OF THE NAVIGATION PERFORMANCE OF ARMY AVIATORS UNDER NAP-OF-THE-EARTH CONDITIONS.		5. TYPE OF REPORT & PERIOD COVERED --
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) (10) Michael L. Fineberg, David Meister and John P. Farrell		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-OT) 5001 Eisenhower Avenue, Alexandria, VA 22333		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) 2Q164715A757
11. CONTROLLING OFFICE NAME AND ADDRESS Army Deputy Chief of Staff for Operations Washington, DC 20310		12. REPORT DATE (11) August 1978
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) -- (12) 38 p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Helicopter navigation
Helicopter flight training
Nap-of-the-Earth (NOE) flight
Transfer of training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The introduction of Nap-of-the-Earth (NOE) tactics presents special difficulties to Army rotary wing aviators, particularly in navigation. The extent of terrain in the navigator's field of view is greatly reduced, owing to the proximity to the ground; also, the interpretation of the terrain features depicted on an aerial map is difficult because the view is much more oblique than in normal flight. -> next page

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cont. This research effort had four specific goals:

(1) To determine the present level of aviation NOE performance,

(2) To develop and evaluate a qualitative NOE navigation performance measure,

(3) To measure the effects of additional terrain-analysis training, and

(4) To measure the effects of flight experience on NOE performance.

Thirty-five Army rotary wing aviators with varying levels of flight experience were tested in a series of field experiments during which they flew simulated operational missions in a UH-1H aircraft to determine their Nap-of-the-Earth navigation proficiency. The mission profile was to navigate a specified route starting from an initial point at Nap-of-the-Earth levels and identify all landing zones while staying within 250 meters of the course line. The results of this study indicated that (1) The NOE navigation skill can be improved with training, and (2) Flight experience (i.e., flight time) does not, in itself, result in improved NOE navigational skills. The findings from this study formulated the departure point for a thorough analysis of the NOE navigation requirements leading toward an NOE navigation instructional program for Initial Entry Rotary Wing (IERW) and operational units.

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HUMAN FACTORS IN TACTICAL OPERATIONS TECHNICAL AREA

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Department of the Army

August 1978

Army Project Number
2Q164715A757

Aircrew Performance

ARI Research Reports and Technical Papers are intended for sponsors of R&D tasks and other research and military agencies. Any findings ready for implementation at the time of publication are presented in the latter part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The research reported in this paper was conducted by the Human Factors in Tactical Operations Technical Area of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). The research program has as its objective the application of scientific research to principles of human performance in complex man/machine systems, in this case the optimization of helicopter Nap-of-the-Earth (NOE) navigation and control effectiveness. The research was conducted under Army Project 2Q164715A757, "Aircrew Performance," FY 1974 Work Program. ARI Research Report 1190, Technical Paper 277, and Research Memorandum 76-26 also present aspects of the initial Technical Area research. The ARI Field Unit since established at Fort Rucker, Ala., with Charles A. Gainer as chief, now conducts the research on aircrew performance. ARI Research Reports 1197, 1198, and 1199 describe the continuing program.

As part of the Aircrew Performance work unit effort, this study was conducted to determine the level of NOE navigation proficiency and to measure, by means of an ARI-developed human performance measurement technique, the effects of training and experience on proficiency level. The research is part of ARI's total program of research in support of special requirements of the Deputy Chief of Staff for Operations (DCSOPS). It was conducted with the cooperation of the Army Aviation Center (USAAVNC) at Fort Rucker, Ala., and the U.S. Army Training and Doctrine Command (TRADOC) and Forces Command (FORSCOM). Special acknowledgement is made to MG W. J. Maddox, Jr., Commander of the Army Aviation Center, and BG J. H. Merryman, Director of Army Aviation (during the period in which the research was conducted), without whose support this research would not have been possible. CPT H. Cook, CW2 P. Ross, and CW2 R. Beatty served as technical advisers, test pilots, and instructors during this research, and CPT J. Isenhower served as project officer at Fort Rucker.

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AN ASSESSMENT OF THE NAVIGATION PERFORMANCE OF ARMY AVIATORS UNDER NAP-OF-THE-EARTH CONDITIONS

BRIEF

Requirement:

The basic objective for this series of studies was to obtain empirical data on how the NOE navigational skill level of Army aviators is affected by (1) pilot experience, defined as the number of flight hours, and (2) two levels of training--a 7-hour terrain analysis course and a 6-hour NOE course. Other objectives were to define a baseline on pilot navigation proficiency and to develop a field research methodology to measure pilot performance in NOE flight.

Procedure:

A total of 35 Army rotary wing aviators participated in three field experiments in which they flew representative NOE navigation missions in UH-1H aircraft. Their flight experience was 200-2,700 hours for 14 experienced pilots, 1,000-3,750 hours for 14 instructor pilots, and 200 hours for 7 Aviation School graduates. Half received the special training. The aviators were assigned missions in which designated landing zones had to be found for simulated medical evacuations or supply deliveries. All 35 aviators navigated at least six NOE routes ranging from 23 to 25 kilometers (km) in length. Twenty-eight of the aviators were also tested on aircraft control and the performance of various NOE maneuvers.

Findings:

NOE navigation is a trainable skill. Experienced aviators with training performed better than experienced aviators without training. In addition, recent graduates with 15 hours of NOE training performed better than experienced aviators without training.

Specialized training in NOE navigation is valuable. The instructor pilots indicated that experience is more important in aircraft control than in navigation. The group with an average of 1,380 flight hours controlled their aircraft better than the group with 200 hours, but this difference in experience appeared to have no effect on the navigation task.

The field research measures and techniques developed for these experiments seemed well suited for NOE navigation research. The objective mission success score (OMSS), a composite performance measure indicating the probability that the mission would be successfully completed, proved useful and has a .75 correlation with subjective rating by expert NOE instructor pilots. As expected, it was shown that NOE navigation is an extremely difficult and complex task. The OMSS's show that NOE missions flown over the Fort Rucker terrain resulted in an overall probability success of .63.

Implications of Findings:

All pilots need more NOE navigation training, which should include a more systematic academic NOE navigation training course, both in initial entry training and at operational units. Academic training should emphasize checkpoint selection and identification, since most of the variance in the OMSS's is attributable to errors in locating landing zones. This recommended training could utilize multimedia methods (e.g., film, tape recordings, slides) and should emphasize practical exercises rather than standard lecture techniques.

Because of its sensitivity to navigation performance, the OMSS should be further refined and validated for use throughout Army aviation in evaluating and diagnosing NOE navigation proficiency.

AN ASSESSMENT OF THE NAVIGATION PERFORMANCE OF ARMY AVIATORS UNDER NAP-OF-THE-EARTH CONDITIONS

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AN ASSESSMENT OF THE NAVIGATION PERFORMANCE OF ARMY AVIATORS UNDER NAP-OF-THE-EARTH CONDITIONS

INTRODUCTION

In response to the highly sophisticated air defense threat of a potential enemy, the U.S. Army has refined a terrain flight tactic for use by its aviation units. This tactic has been designated Nap-of-the-Earth (NOE) flight (i.e., flight at treetop level and below), using existing terrain features to mask the aircraft from enemy radar and optical detection. This mode of flying will enhance survivability and mission effectiveness near the forward edge of the battle area.

The increased use of NOE tactics presents a number of problems not previously encountered by Army rotary wing aviators. The primary problem is in navigation. The difficulty in navigation can be attributed to several factors:

1. The limited forward view when operating in close proximity to the ground.

2. The perspective at which checkpoints are viewed.

3. The design of aerial charts, which does not take into account navigation from the NOE altitudes.

To improve aviator NOE navigation ability, a research effort was initiated first, and then familiarization programs were introduced into the Initial Entry Rotary Wing (IERW) program and were implemented at operational units. Once changes to the training program were established, they had to be evaluated and revised, as necessary. Further, for evaluations to be meaningful and their results comparable, a standardized assessment technique was required. Because the traditional performance measurement techniques for aviators did not readily adapt to the NOE situation[1], owing to the lack of standardization, development of such a standardized technique was one objective of the research.

This report describes three separate experiments, all performed to measure the following:

1. The effectiveness of present NOE training as shown by the pilot's ability to navigate his aircraft over unfamiliar terrain at NOE altitude,

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[1]Farrell, John P. Measurement Criteria in the Assessment of Helicopter Flight Performance, presented at conference on Aircrew Performance in Army Aviation, Fort Rucker, Alabama, November 1973.

2. The effect of additional terrain analysis training on NOE navigation,

3. The effect of flight experience on NOE navigation ability, and

4. The utility and applicability of the measurement techniques used in the field environment.

These experiments were preliminary and were designed to be an empirical evaluation of the navigation problem. The work reported here was conducted from 24 September 1973 to 20 December 1974 at the U.S. Army Aviation Center (USAAVNC), then the Aviation School; it was the first step in direct support to the Deputy Chief of Staff for Operations (DCSOPS) operational objective: "to determine the most effective type and amount of training needed to develop satisfactory proficiency in NOE-type flying."

METHOD

Subjects

The subjects in this study were 35 Army helicopter pilots who were currently proficient in the UH-1H helicopter and had some exposure to NOE flight, at either entry or unit level. The pilots were selected to represent three different experience levels. The 14 pilots in Experiment 1 were selected to represent the general population of Army UH-1H helicopter pilots; their experience ranged from 200 to 2,700 flight hours.

The 14 subjects in Experiment 2 were selected to obtain a sample of the more proficient, instructor-level UH-1H helicopter pilots; their flight experience ranged from 1,000 to 3,750 flight hours.

The seven subjects in Experiment 3 were selected as representative of recent graduates of Army Aviation School who had also recently completed a new 15-hour course in NOE navigation. These pilots had accrued 200 flight hours.

Prior NOE experience was more difficult to specify. The 200-hour pilots in Experiment 3 did have a 15-hour course in NOE navigation, but the NOE experience of pilots in Experiments 1 and 2 varied. All were required to have had at least some unit training in NOE. However, the extent and the definition of the training varied widely.

Facilities

Test Range. The test range used in all experiments is located west of Troy, Ala., and is shown on standard (1:50,000 scale) map sheets

designated Lapine (3747 IV) and Youngblood (3747 I). The area is heavily wooded, with numerous small fields and open areas and many small streams and low-lying marsh areas throughout. The land itself is gently rolling terrain that, by consensus, presents a very difficult NOE navigation problem.

The range was divided into three areas of operation; each area was further divided into four routes, each containing an initial point (IP), intermediate landing zones (LZ's), and a release point (RP) designating the end of the mission.

Aircraft. Two UH-1H aircraft were employed in the study. The first, designated the "low ship," was used to transport the subject pilot, instructor/safety pilot, and the ARI test supervisor. The second, designated the "high ship," served two purposes: it flew "chase" for safety reasons, and it provided the high-altitude platform, at approximately 800 feet, from which a second instructor pilot could track the flight of the low ship for experimental purposes.

Visual Aids. The following materials were used in the terrain analysis training provided during the study: (1) Petrey 1:50,000 Experimental Map Sheet, Day Use, Series V744 AMD, Sheets 3747 I and IV, and (2) 35mm color slides of the three areas of operation.

Test Personnel. Four Army aviators were required to conduct the tests. Two were highly qualified NOE instructor pilots. One acted as pilot in the low ship and the subject pilot served as navigator. The other instructor pilot served as tracking observer in the high ship. His role was to follow the flight of the low ship and trace its ground track on a map in relation to the prescribed course previously drawn on the map. The other two aviators alternated in flying the high ship. The two instructor pilots also served as technical advisers during design and implementation of these tests.

Safety. All provisions of USAAVNC Supplement I to Army Regulation 95-1, 385-10 and 40 were strictly observed.

Experimental Design

Experiment 1. The independent variables were the presence or absence of terrain analysis training and the level of flight experience.

To determine the effects of these variables on inflight navigation skill, seven pairs of subjects were systematically matched for experience. One member of each pair was randomly assigned to an experimental group and the other to a control group. The control group (A) flew 12 flights in three phases. Each phase was flown over a different area so that, although a pilot may have become somewhat familiar with the general area of operations (AO), he never flew the same route twice. The

experimental group flew eight flights, standing down between Phase I and Phase III for a 2-day terrain analysis course prepared and presented by the instructor pilots. The course consisted of a 3-hour review of a programed text on navigation and a 3-hour terrain association exercise. During this part of the course the subject was shown slides of different points in each AO and asked to report his position on a standard 1:50,000 scale map.

To control for differences in the terrain composition in each AO, the order in which the areas were overflown was systematically varied between subjects. For example, Subject 1 flew areas I, II, III in that order, whereas Subject 3 flew areas III, II, I. The effects of the independent variables were measured in terms of navigation proficiency.

Experiment 2. The purpose of Experiment 2 was to validate the techniques and methodology used in Experiment 1 and to expand the subject population. The 14 subjects in Experiment 2 were all highly qualified NOE instructor pilots or had served as members of a Modern Army Selected Systems Test, Evaluation and Review (MASSTER) evaluation team of Chief of Development Evaluation Command (CDEC) "night owl" team. The background and design of this experiment were essentially the same as Experiment 1, with the following exceptions:

1. Pilots were assumed to be at a higher skill level,

2. The variable of flight experience was deleted,

3. The number of flights was reduced to 10 (i.e., 3 over each area of operations and 1 aircraft handling flight), and

4. Both control and experimental groups navigated over the same number of flights.

Experiment 3. The purpose of Experiment 3 was to measure the effectiveness of the 15-hour NOE navigation course that had replaced the original 6-hour NOE familiarization sequence. The subjects used in this study were the most recent (Dec. 1974) graduates of the USAAVNS Initial Entry Rotary Wing (IERW) program. Each of these pilots had taken the 15-hour NOE sequence. These pilots flew six flights, i.e., two over each of three areas of operation. The design was otherwise identical to Experiment 2.

Procedures

Upon being selected, each subject was given an information pamphlet containing a description of the purpose and design of the study, along with administrative information. Upon reporting to the project officer at Fort Rucker, the subject was thoroughly briefed again and was asked

to fill out a biographical data sheet. Prior to each mission, the subject received a premission briefing at the Lowe Heliport Field Office. The briefing was conducted by the Senior Instructor Pilot and consisted of three parts:

1. A presentation and discussion of the day's mission,

2. Map analysis of the route to be followed, and

3. A review of flight safety procedures, if necessary.

The subject pilot received his NOE route assignment to be flown that day. The appropriate map sheet was provided with the route marked in yellow, and with the IP, LZ, and RP designated. An identical map was given to the observer who flew in the high ship.

On a typical flight, the subject pilot, instructor pilot, and ARI test supervisor manned the low ship. The subject pilot then navigated at an altitude of 800 ft. from the point of hover check to the IP of the NOE route, with the high ship flying chase. The subject pilot's identification of the IP was scored by the instructor pilot as correct or incorrect.

The subject pilot then began flying the route at NOE altitude, following as accurately as possible the prescribed course on the map. The actual course flown by the subject pilot was recorded by the high ship observer. The subject was required to identify and stop at each intermediate LZ. The subject pilot's selection of each LZ was scored by the instructor pilot as correct if the landing was within 100 meters of the correct landing zone.

At the end of the mission the instructor pilot took control of the aircraft and flew to the refueling point at Troy Army Airfield. Here the subject was debriefed, shown the actual track flown, and told where he went off course. The subject pilot was asked to review the mission and to indicate the reasons for navigational decisions. After the debriefing, the high ship observer's map was retained by the ARI test supervisor. Most of the dependent measures were derived from this map.

After a short rest of approximately an hour, the experimental group flew the second mission of the day.

Samples of inflight intercommunications during Experiment 1 were recorded by the ARI observer for evaluation purposes and further research into inflight communication techniques. Observations of the subjects' navigational procedures were also recorded (see the Conclusions section of this report). After each flight, the instructor pilot subjectively evaluated the effectiveness of the mission in terms of three categories: complete success, partial success, or failure.

Data

At the end of each flight the following data were collected by the ARI test supervisor:

1. The annotated map containing the subject's actual track and other measures of checkpoint identification (see Figure 1 for a representative map),

2. The instructor pilot's evaluation of mission effectiveness, and

3. Behavioral observations and critical times during the mission.

Dependent Measures

The following set of dependent measures was derived from these data and used in all three experiments to measure navigation performance.

Mission Success Scores. Two measures of mission success were employed: a subjective mission success score (SMSS) and an objective mission success score (OMSS).

1. SMSS--As discussed under "Procedures," the instructor pilot was asked to rate the subject's navigational effectiveness in terms of three categories: complete failure, indicated by zero; partial success, indicated by 1; and complete success, indicated by 2. This rating considered any evidence of disorientation along the route and any assistance that had to be given to the pilot by the instructor. For example, if the instructor had to fly the subject back to the correct route because the pilot became completely disoriented, a failure rating of zero would be given.

   This rating was then divided by 2 (the criterion for complete success), yielding a measure ranging from .00 to 1.00. If the subject was completely successful on all flights, he would receive a rating of 1.00. A mean subjective mission success score across all flights for each subject was then calculated.

2. OMSS--This measure was constructed to serve as a composite metric representative of the subject's scores on four individual measures (see Figure 2). The four measures used were number of IP's missed, number of LZ's missed, number of 250-meter excursions from the course line, and number of 1,000-meter excursions. Each of the four measures was weighted on the basis of responses gathered from a questionnaire distributed to 15 veteran combat pilots.

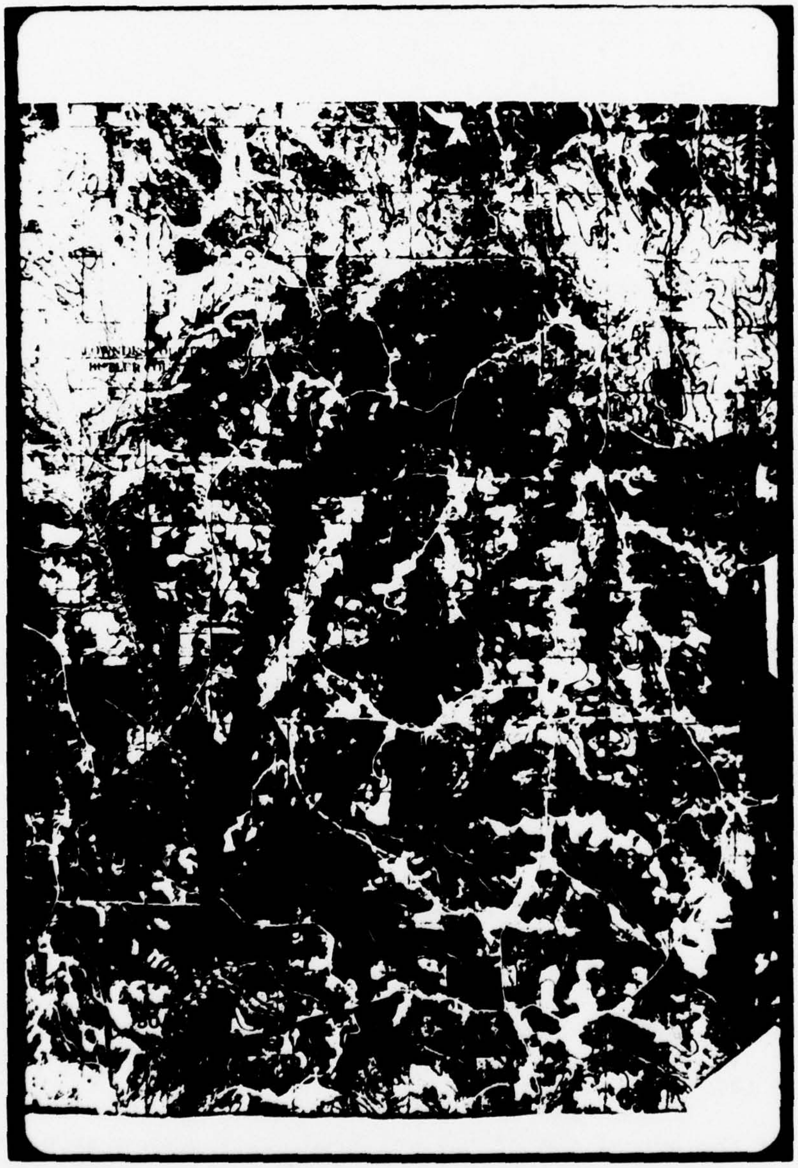

Figure 1. Subject performance described in sample flight track.

$$OMSS = 1 - \frac{\frac{W_1}{SD_1} X_1 + \frac{W_2}{SD_2} X_2 + \frac{W_3}{SD_3} X_3 + \frac{W_4}{SD_4} X_4}{F},$$

where X equals the number of occurrences in each error category:

X_1 = IP failures,

X_2 = LZ failures,

X_3 = 250-meter excursions, and

X_4 = 1,000-meter excursions;

and W equals the empirically determined weight of each error:

$W_1 = 9$,

$W_2 = 9$,

$W_3 = 3$, and

$W_4 = 7$;

therefore:

$$\frac{W_1}{SD_1} = K_1 = 22.50,$$

$$\frac{W_2}{SD_2} = K_2 = 25.71,$$

$$\frac{W_3}{SD_3} = K_3 = 4.76, \text{ and}$$

$$\frac{W_4}{SD_4} = K_4 = 18.91;$$

and F equals a score which represents complete mission failure:

$F = 100$.

Note: If the actual sum of the weighted error scores exceeded 100, the OMSS was still scored as zero.

Figure 2. Calculation of OMSS.

The responses were then tabulated and a mean weight for each error measure was calculated. The weights were as follows:

Failure to find IP--9,
Failure to find LZ--9,
250-meter excursion--3, and
1,000-meter excursion--7.

Each weight (W) was then adjusted by dividing by the standard deviation (SD) of the raw error scores under each category across all subjects. Next, the number of errors (X) in each category was determined for each flight. The number of errors in each category was then multiplied by the associated adjusted weight. The weighted totals were summed across categories and this sum was then divided by 100 (F); the value of 100 was chosen as a convenience and because scores of 100 would represent total mission failure, since the OMSS is based on the number of errors.

The formula is as follows:

$$\text{OMSS} = 1 - \frac{\frac{W_1}{SD_1} X_1 + \frac{W_2}{SD_2} X_2 + \frac{W_3}{SD_3} X_3 + \frac{W_4}{SD_4} X_4}{F} .$$

The result of this calculation was subtracted from 1 to indicate the objective mission success score (see Figure 2).

SMSS and OMSS are composite measures: they tend to reflect the totality of the subject's navigational performance. The measures are "part" measures: they describe individual elements of the total mission.

Probability of Finding IP (PIP). This measure was determined by dividing the number of IP's found by the total number of IP's that existed across all flights. For example, if Subject 1 flew 9 flights and found 5 IP's, the PIP would be 5/9 = .55.

Probability of Finding LZ (PLZ). This measure was calculated by dividing the number of correctly found LZ's by the total number of possible LZ's across all flights for that subject. For example, if Subject 1 correctly found 15 LZ's out of a total of 23, the PLZ would be 15/23 = .65.

250-Meter Excursions (250 EXC). This measure indicates the number of times that the pilot deviated from the center of the specified course line by more than 250 meters but less than 1,000 meters. The number of such excursions was summed over all flights for each subject.

1,000-Meter Excursions (1,000 EXC). This measure indicates the number of times the pilot deviated from the center of the prescribed course line by more than 1,000 meters. The number of such excursions was summed across all flights for each subject.

Total Distance Traveled (TDT). This is the distance covered by the pilot over all flights measured, including all excursions, from the IP to the RP.

Percentage of Distance Traveled Off-Course 250 Meters (PDTOC 250). This measure relates the number of 250 EXC to the TDT. It is calculated by dividing the distance traveled during all 250 EXC summed over all flights by the TDT for each subject. For example, if Subject A flew a TDT of 168,000 meters and traveled 16,800 meters in 250 EXC, his PDTOC would be 10%.

Percentage of Distance Traveled Off-Course 1,000 Meters (PDTOC 1,000). This measure relates the number of 1,000 EXC to the TDT and is calculated the same as PDTOC 250.

Percentage of Distance Traveled On-Course (PDTOnC). This measure was calculated in order to provide a one-number indicator of the continuous measure of navigation. For example, if Subject A had a PDTOC 250 of 10% and PDTOC 1,000 of 6%; the PDTOnC = 1.00 -10% -6% or 84%.

Time. This is the mean time in minutes across all flights for each subject calculated from the IP to the RP or ended at the discretion of the test supervisor.

RESULTS

The results of these studies are presented as individual experiments. The statistical test for significance used in most cases was the Mann Whitney U[2], because many of the measures were ordinal rather than interval. The Mann Whitney U retains most of the power of the t-test, while not constraining the researcher to the latter's assumptions. The Mann Whitney U is most valuable when samples are small and the underlying distribution is not necessarily normal.

Experiment 1

Overall Performance Level. The data in Table 1 represent mean scores for 14 subjects across all flights for each of the navigation

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[2] Siegel, S. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Co., 1956.

measures described in the Procedure Section. The OMSS varies from .38 to .79 with a mean of .57. The SMSS mean was .54 with scores varying from .17 to .79. The mean PIP and mean PLZ for all subjects was .76 and .69, respectively.

Two measures were used to quantify the distance traveled off-course. These measures approximate the 500- and 2,000-meter corridors; breaking these corridors results in 250- and 1,000-meter excursions respectively. Table 1 indicates that the Army aviators involved in the study made approximately twelve 250 meter excursions and four 1,000-meter excursions during the course of 7 flights.

The present distance flown outside the 500-meter acceptable corridor (PDTOC 250) for all pilots was 12.80%. The mean PDTOC 1,000 of 5.94% is smaller. Pilots who made mistakes of this magnitude, and were unable to correct their errors within a 5-minute period, were considered by the instructor pilot as lost and were vectored back to the course line.

The PDTOC was 81.27%. This means that a pilot returning from the forward edge of battle area (FEBA) and required to maintain a 500-meter corridor would have an 18% chance of straying outside the 500-meter corridor.

Terrain Analysis Training Effect. The navigation data presented in Table 2 reflect the performance of those pilots in the control group, (no terrain analysis training) and those in the experimental group (with terrain analysis training). To control for the additional flying experience gained by the control group (which did not stand down for training), Phase II of the control group flights was compared with Phase III of the experimental group. The means for each subject are therefore based on three flights rather than on all flights measured.

The data in Table 2 show that the group which received map training found the checkpoints (PIP and PLZ) more often and stayed within the 1,000-meter corridor more often than did the group without map training. This better performance is reflected in the two overall measures: the trained group had an SMSS of .60 and an OMSS of .59, whereas the untrained group scored .50 on SMSS and .51 on the OMSS. Although the differences are not statistically significant at the conventional .05 level of confidence, there is an apparent trend, which indicates support for the hypothesized benefits of additional map training.

There is a statistically significant difference ($p = .006$) in the ability of the two groups to find checkpoints. The trained group had a .86 PIP, and the untrained group scored .67. The significance level is .006.

Table 1
Summary Data for All Subjects for All Flights in Experiment 1

Error Measures / Subject	Mission Success Score		Probability of Finding		No. of 250 Meter Excursions	No. of 1000 Meter Excursions	Total Distance Traveled (Meters)	% Distance Traveled Off Course >250 <1000M	% Distance Traveled Off Course >1000M	% Distance Traveled On Course	Time
	SMSS	OMSS	IP	LZ							
1	.43	.42	.50	.42	6	6	187,800	6.07	11.98	81.95	33.12
2	.67	.79	1.00	.86	6	1	128,000	10.55	.70	88.75	26.16
3	.50	.55	.75	.80	15	6	200,100	10.84	6.50	82.66	30.62
4	.17	.42	.50	.60	15	4	122,400	20.30	7.27	72.43	21.66
5	.25	.38	.87	.56	18	8	187,500	18.83	14.93	66.24	37.50
6	.63	.61	.75	.75	7	1	101,800	19.16	2.46	78.54	35.00
7	.56	.65	.75	.69	12	2	218,400	12.39	5.72	81.89	27.62
8	.67	.57	1.00	.61	12	1	155,000	12.19	3.67	84.14	32.66
9	.79	.79	1.00	.83	10	2	207,000	6.90	2.70	90.40	26.55
10	.30	.53	.40	.54	15	3	147,500	17.02	5.59	77.39	39.20
11	.61	.47	.67	.61	16	5	211,100	13.16	6.30	80.54	22.77
12	.83	.70	1.00	.89	15	3	173,000	14.45	6.00	79.46	25.00
13	.38	.51	.62	.66	10	5	170,800	9.45	2.81	87.74	25.00
14	.75	.65	.83	.89	7	4	148,300	7.90	6.40	85.70	26.16
MEAN	.54	.57	.76	.69	11.71	3.64	168,479	12.80	5.94	81.27	29.22
STANDARD ERROR	.055	.035	.055	.039							
CI .95	.43-.65	.50-.64	.65-.87	.61-.77							

Table 2

Comparison of Groups With and Without Terrain Analysis Training in Experiment 1

	2 A NAV Measure									
Subjects	SMSS	OMSS	PIP	PLZ	250 EXC	1,000 EXC	PDTOC 250	PDTOC 1,000	PDTOnC	TIME
Pilots with training N = 7	.60	.59	.86	.75	5.74	.71	16.95	3.04	79.99	28.67
Pilots without training N = 7	.50	.51	.67	.63	3.71	2.28	10.11	9.57	80.30	32.23
Mann Whitney U test	ns	ns	**	ns	ns	*				

$^{*}p < .05$.
$^{**}p < .01$.

The terrain-analysis-trained sample took 4 minutes less, on the average, to complete their missions and flew 8,000 meters less than the nontrained sample. This indicates that they stayed closer to the course line than the other group. This is further supported by the fact that the nontrained group flew 6% more of its total distance off-course by more than 1,000 meters than did the trained group (see Column PDTOC 1,000). However, none of these differences was statistically significant.

Effects of Experience. Table 3 presents the navigation data from Table 1, grouped according to experience level. The high-experience group had a mean flight hour experience level of 1,387 hours, and the low-experience group had 214 hours.

On first inspection of these data, the results appear paradoxical. The low-experience group did better in all measures than the high-experience group. However, this observation must be qualified by the very small differences between the groups.

Table 3

Comparison of the High-Experience Group (1,387 mean flight hours) With the Low-Experience Group (214 mean flight hours) in Experiment 1

	3 A NAV Measure									
Subjects	SMSS	OMSS	PIP	PLZ	250 EXC	1,000 EXC	PDTOC 250	PDTOC 1,000	PDTOnC	TIME
High-experience pilots N = 7	.51	.56	.74	.68	13.70	3.71	15.69	6.47	77.85	29.67
Low-experience pilots N = 7	.57	.59	.79	.70	9.71	3.57	9.91	5.39	84.69	28.76
Mann Whitney U test	ns	ns	ns	ns	*	ns				

*p < .05.

Experiment 2

In Experiment 2, 14 highly experienced NOE instructor pilots were evaluated in terms of their navigation ability. The design and procedures of this experiment were the same as those for Experiment 1, with the exceptions noted earlier in the Method section.

Comparison Measures. Table 4 compares the navigation scores of the NOE instructor pilots to those of the "average" aviators in Experiment 1. The scores of the NOE instructor pilots in five of the six measures are significantly better than those of average pilots (Mann Whitney U, $p < .05$). The instructor pilots seem to have maintained course more efficiently, as indicated by the higher percentage of distance traveled on course. They did, however, make significantly more 250-meter excursions than the average group. This did not adversely affect the percentage of distance traveled on course, because the extent of these excursions was not as great as the extent of excursions committed by the pilots in Experiment 1.

Table 4

Comparison of Scores Between "Average" Pilots and NOE Instructor Pilots in Experiment 2

	4 A NAV Measure									
Subjects	SMSS	OMSS	PIP	PLZ	250 EXC	1,000 EXC	PDTOC 250	PDTOC 1,000	PDTOnC	TIME
NOE Instructor pilots N = 14	.75	.65	.93	.79	18.00	3.40	10.80	3.76	85.44	30.00
Average pilots N = 14	.54	.57	.76	.09	11.71	3.64	12.80	5.94	81.27	29.22
Mann Whitney U test	*	**	**	*	*	ns				

*p < .05.
**p < .01.

Experiment 3

This experiment was designed to compare the navigation performance of two groups of recent IERW graduates uncontaminated by varying levels and types of operational experience. The first group (Sept. 1973 graduates) received only the 6-hour NOE familiarization sequence, whereas the other (Dec. 1974 graduates) received a 15-hour NOE navigation course.

Comparison Measures. Although there is not complete concurrence among the navigation measures used in Table 5, there is a general tendency in favor of the 15-hour group. The 15-hour group is superior to the 6-hour group on 8 of the 10 measures used, and on 2 of these measures the effect is statistically significant. The OMSS for the 15-hour group is .70 and the OMSS for the 6-hour group is .60. The 15-hour group has a .90 probability of finding the IP, and the 6-hour group achieves only a .78 probability. Both of these differences are statistically significant (Mann Whitney U, $p < .05$).

Table 5

Comparison of Performance Scores Between 200-Hour IERW Graduates With 15 Hours NOE Training and Those With 6 Hours NOE Familiarization Experiment 3

	5 A NAV Measure									
Subjects	SMSS	OMSS	PIP	PLZ	250 EXC	1,000 EXC	PDTOC 250	PDTOC 1,000	PDTOnC	TIME
Pilots with 15-hr training N = 7	.70	.70	.90	.87	15	2.33	10.52	2.69	86.79	24.86
Pilots with 6-hr training N = 6	.54	.60	.78	.74	7	3.16	9.69	6.23	84.08	28.61
Mann Whitney U test	ns	*	*	ns	**	ns				

*p < .05.
**p < .01.

A somewhat anomalous finding is that on 2 of the 10 measures (frequency of 250 EXC and PDTOC 250) the 6-hour group was superior to the 15-hour group. The 250 EXC was statistically significant ($p < .01$) but the difference on the PDTOC 250 was quite small, with the 15-hour group having only about 1% more distance off-course than the 6-hour group. This effect is difficult to account for; a probable explanation is that the 15-hour group made more minor excursions because they were traveling at a higher airspeed. The fact that the 15-hour group covered the distance in less time, on the average, indicates that errors were discovered more quickly and corrected more effectively than were the errors made by the 6-hour group.

Combined Results. The scores for all 35 pilots were combined. The sample did represent a wide range of flight experience (200-3,600 hours) and NOE training (6 hours NOE familiarization to qualification as NOE

instructor pilot). In generalizing from these results, the user must be cautious, as several possible factors could have influenced the data of this small sample. For example, the 14 instructors could have inflatable data. In addition, the restricted terrain sets limits on generalization.

The statistic employed for the purpose of generalization is the standard error of the mean and associated 95% confidence limits. This allows inference from the sample to the total population within specified limits of certainty. Table 6 presents the sample means, standard errors, and 95% confidence limits for all navigation measures.

The data in Table 6 indicate that the aviators achieved on OMSS of .63, with a standard error of .0259. The confidence interval ranged from .58 to .68. This indicates that 5% of the time the mean OMSS for a similar population of Army aviators falls somewhere in this interval. The SMSS can be interpreted similarly. The sample mean SMSS is .65 with a standard error of .0361 and a confidence interval extending from .58 to .72. Each of the other navigation scores may be interpreted in a similar manner.

Table 6

Mean Performance Scores, Standard Errors, and Associated Confidence Intervals for All Pilots (N = 35) Over All Flights (242)

	6 A NAV Measure									
Subjects	*SMSS*	*OMSS*	*PIP*	*PLZ*	250 *EXC*	1,000 *EXC*	PDTOC 250	PDTOC 1,000	PDTOnC	TIME
Mean N = 35	.65	.63	.85	.77	14.86	3.23	11.44	4.32	84.32	29.00
Standard error	.0361	.0259	.0281	.0024	1.0217	.4122	.8468	.6681	1.2938	.8579
Confidence limit (95%)	.58-.72	.58-.68	.80-.90	.73-.81	12.86-16.86	2.42-4.04	9.78-13.10	2.97-6.67	81.78-86.86	27.32-30.68

Table 7 subdivides the 35 subjects into five groups of 7 subjects each. The breakdown was conducted along two variables--training and experience. This categorization is primarily for summary purposes, as the groups were previously compared in terms of the individual experiments. When interpreting these data, one must remember that the results from the first experiment were based on three flights per subject, whereas the results for the other experiment were based on at least six flights per subject. The five groups as distributed by experiment are as follows:

Experiments

1. Average aviators with on-the-job training,

   1

2. Average aviators without on-the-job training,
3. NOE instructor pilots with on-the-job training, 3

   2

4. NOE instructor pilots without on-the-job-training, and
5. Average aviators with NOE navigation training during IERW program.

In Table 7, these groups are compared in terms of navigation scores. For the OMSS, the data show that the average aviators with early NOE training tend to perform more effectively than the other groups. They also show the highest probability of finding the LZ (.85), in comparison with other types of aviators tested. The fact that this component is weighted heaviest in regard to mission success accounts for the high OMSS for average aviators with early NOE training, as compared to the NOE instructor pilots with training who scored .64 on OMSS, but only .76 on finding the LZ.

For the SMSS, the NOE instructor pilots with training scored highest (.82) of the five groups, and the instructor pilots without training were next with .80.

In finding the IP of each mission, the instructor pilots without additional training scored .95.

Table 7

Comparison of Performance Scores
Among Five Groups of NOE Aviators

	7 A NAV Measure									
Subjects	SMSS	OMSS	PIP	PLZ	250 EXC	1,000 EXC	PDTOC 250	PDTOC 1,000	PDTOnC	TIME
Avg pilots with training	.60	.59	.86	.75	5.14	.71	16.95	3.04	79.99	28.67
Avg pilots with no training	.50	.51	.67	.63	3.71	2.28	10.11	9.57	80.30	32.23
Instructor pilots with training	.82	.64	.91	.76	15.00	2.00	10.63	2.47	86.90	29.57
Instructor pilots no training	.80	.63	.95	.81	21.00	4.85	10.41	4.97	84.62	30.00
Avg pilots 15-hr NOE	.70	.70	.90	.87	15.00	2.33	10.52	2.09	86.79	28.61

DISCUSSION

Effectiveness of Existing NOE Training

The first and most obvious implication from the results of these experiments is that Army pilots require specialized NOE navigation training. Statements pertaining to the mission effectiveness of this performance in a tactical situation must be qualified, since the test situation cannot represent combat. If the OMSS is a valid score, it is assumed that the Army would prefer that the average OMSS for navigation would approach, even if it does not reach, 1.00 rather than the .63 which represented actual accomplishment (see Tables 1, 4, 6, and 7).

Checkpoint identification (map/terrain association) appears to be the primary and most critical error made in NOE navigation. This finding is based upon the fact that 15 operational combat pilots who rated the importance of the various NOE elements weighted the two errors dealing with checkpoint identification as the most critical to successful mission completion. On a scale of 10, the mean weights for failure to find the IP and LZ were both 9.

It appears, from the overall navigation scores and from the meaures of checkpoint identification, that the major cause of low navigation scores is the lack of ability to identify and associate terrain features with points on a map.

It was originally thought (based on Experiment 1) that correct identification of checkpoints and greater congruency in map/terrain association would result in improved course maintenance performance. An aviator who has the objective LZ firmly located by means of map/terrain association can devote more time and effort to maintaining the prescribed route and staying within a specified corridor.

This hypothesis was not supported by the results of later experiments. It appears (see Table 7) that as aviators get better at checkpoint identification, they tend to tolerate deviation from the nominal course line. Improved checkpoint identification ability promotes confidence. Added confidence tends to promote a selection of the best route more readily.

Experience Effects

Experience in flight at higher altitudes does not appear to have transfer to navigation at NOE altitude. In Experiment 1, the experienced pilots without specialized NOE training did not perform any better than the graduates with only 200 flight hours (see Table 3).

It is also evident from Table 3 that flight experience, per se, does not necessarily improve identification of checkpoints. This suggests that the identification skill could be taught in a classroom or part-task simulation environment.

It is hypothesized that the pilots with low flight time performed at least as well as those with high flight time because they had recently received, as part of their undergraduate tactics course, an NOE flight familiarization sequence. The high-time pilots had received their NOE training on the job at the unit level.

When all the subgroups are compared (see Table 7), the recent graduates of the 15-hour NOE course actually show higher OMSS than do the instructor pilots with or without specialized NOE training. It is likely that the extensive experience in navigating at high altitudes did not generalize to the NOE situation because of the very different visual environment at NOE altitude.

The data in Table 7 indicate that specialized training is warranted for proficiency at NOE navigation. It is evident from these findings that experience alone is not the answer to the problem of NOE navigation performance enhancement.

Terrain Analysis Training Effects

The administration of the experimental map-study course in Experiment 1 resulted in slightly improved navigation performance.

Comparison of map-trained subjects with non-map-trained subjects suggests that checkpoint identification/selection skill does improve with this training. It is possible that specific training applied to terrain analysis could increase overall navigation performance (see Table 1, PLZ).

Improvement in the ability to associate map and terrain should yield improvement in overall proficiency scores. This skill is trainable, as evidenced by the data in Table 2. Checkpoint identification ability does improve as a function of map training. Table 2 shows that experimental training of average aviators improved their ability to find the IP by 19% and their ability to find the LZ by 12%. Since this gain in performance was a function of an admittedly crude and general map-study course, a highly concentrated course structured specifically to teach checkpoint identification might raise this skill level even more.

Training Suggestions

Because the thrust of the NOE flight research performed by ARI is to assist in the development of effective NOE training methods, this report would not be complete without suggesting ways of improving NOE navigation.

It has been demonstrated that the basic problem facing pilots in NOE flight is navigation--a conclusion which will come as no surprise to operational pilots. The experiments described in this report indicate that the basic problem in NOE navigation is terrain analysis, a skill which has two aspects--mission planning and inflight terrain analysis. Both of these aspects should be given additional emphasis in IERW and operational training.

Inflight training of terrain analysis skills is difficult because of the limited opportunity to stop and review environmental inputs and to practice analytic skills. Thus, it appears that much of the needed terrain analysis training should be given in ground academic training.

Based upon both the research findings as well as the personal observation of the ARI investigators, it is suggested that ground academic terrain analysis training should consist of the following elements:

1. Training in the basic principles of topography and cartography,

2. Performance-oriented exercises in interpretation of maps, with special emphasis on analysis of terrain features and their representation on standard maps used in flight,

3. Practice in NOE mission planning with emphasis on identification of checkpoints and use of terrain for masking, and

4. Performance-oriented exercises in NOE navigation, making use of motion picture films of routes flown at NOE.

Such a training program, which should make use of all available media, (film, 35mm slides, tape recordings, vugraphs, paper-and-pencil exercises, etc.) should consume at least 10 working days. Land navigational problem exercises would be performed either concurrently or immediately upon conclusion of the terrain analysis course. This would then be followed by 5 days of inflight practice in actual navigation under controlled flight conditions.

The adequacy of such a training approach toward improving NOE navigational skills should be evaluated by using techniques such as those already developed and described in this report.

Additional Observations

Intracrew Communications. Based on behavioral observations in flight and preliminary review of some of the intercom tapes, it is felt that pilot/navigator communication is often inadequate for NOE navigation. Two areas of deficiency are noted--infrequency of communications and misinterpretation of information. A number of subjects had to be repeatedly prompted by the pilot to provide vectors for flight. Copilots acting as navigators often fail to give the pilot advance information about the checkpoints they are looking for, so that the pilot can act as a second pair of eyes. Terminology in communicating information between pilot and copilot is not standardized. In general, there is a lack of formal communication procedure between copilot and pilot. The development of a standardized procedure should be explored as a means of improving performance at NOE navigation.

Subjective Responses of Pilots. Based on subjective reports collected during mission debriefings, it is felt that the workload on the NOE navigator is very high and accordingly stressful.

Individual differences in capability, possibly of a perpetual nature, may also play a role. This hypothesis needs further research.

Standardized Measurement System. The lack of a standardized performance measurement technique for NOE has been noted. The utility of the OMSS in this study indicates that this metric could be further standardized and evaluated as a possible basic measurement and diagnostic technique in maintaining NOE navigator proficiency.

Characteristics of Expert NOE Navigators. Observations by test personnel flying with the subjects suggest that the successful NOE navigator performs with, among others, the following capabilities.

1. Uses a series of multiple checkpoints or terrain features as a basis for determining whether or not he is on the correct route. Many navigators look for only a single checkpoint, which is more difficult to find than a combination of checkpoints. When they fail to find the single checkpoint, they are more likely to persevere on an incorrect track. Successful navigators tend to recognize more quickly that they are deviating from the specified route and reverse their direction of flight quickly. As a result, their deviations from the specific route are shorter.

2. Can judge more accurately the distance traveled in terms of time. Navigators tend to estimate the distance they must travel to reach a particular checkpoint, but they do this by subjective time. When their time-distance relationship is inaccurate, they tend to become confused with regard to the recognition of checkpoints, because they either anticipate these in advance of their appearance or they overrun them.

3. Warns the pilot in advance of the checkpoints he is looking for, so that the pilot can be looking for them also.

APPENDIX

USARI WEIGHTING INSTRUMENT

The following are representative errors encountered in the Army Research Institute performance measures of NOE navigation ability. Your help as operational combat pilots is necessary to attach the proper importance to these types of errors so that we may concentrate our research effort in the most effective direction. Therefore, please assign a value, from 1-10, to each of these errors, reflecting their impact on combat mission success. The higher the number assigned, the more serious the error. For example, if you were to assign a value of 10 to a 250-meter deviation, this would indicate that a mistake of this type would very seriously compromise combat mission success. If you were to assign a 1, it would indicate that an error of this type would have little, if any, impact on the success of a combat mission.

The error categories are as follows:

- Failure to find or identify an LZ other than the IP.

- A 250-meter deviation from a nominal course line.

- Failure to find the IP.

- A 1,000-meter deviation from a nominal course line.

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